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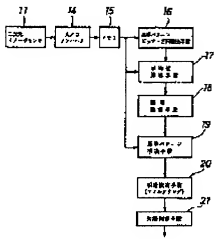
(54) METHOD AND APPARATUS FOR INSPECTING FLAW OF TRANSPARENT BODY

(57)Abstract:
PURPOSE: To accurately discriminate not only the presence but also shape or kind of the flaw of shading properties and the flaw of refractivity even when the flaws are small.
CONSTITUTION: A reference pattern such as a moire pattern wherein light and shade parts are regularly continued at a predetermined pitch P is detected by an image sensor and the pitch P is detected from the number of the pixels of the light and shade parts of the detected pattern and, thereafter, the reference pattern is detected by the image sensor through a transparent body being an object to be inspected and a threshold value is set from the average value of two pixel data separated by a predetermined number of pixels based on the pitch P with respect to the pixel data and the light and shade of each pixel are judged according to the threshold value to judge a flaw from the number of the light and dark parts thereof.



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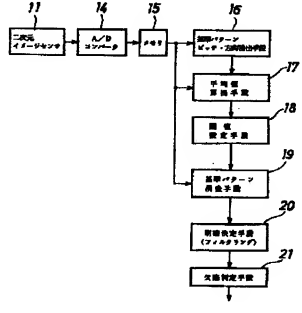
(54)【発明の名称】　透明物体の欠陥検査方法とその装置

(57)【要約】
【目的】　遮光性の欠陥及び屈折性の欠陥のいずれについても、その有無は勿論のこと、その形状や種類までも判別することができ、しかも欠陥が小さくともその判別を精度良く行えるようにする。
【構成】　明暗が所定のピッチＰで規則性をもって連続するモアレ等の基準パターンをイメージセンサで受光し、その受光したパターンの明暗の画素数からピッチＰを検出した後、基準パターンを検査対象の透明物体を透してイメージセンサで受光し、その画素データに対し、ピッチＰを基準とする所定画素数だけ離れた２つの画素データの平均値から閾値を設定し、この閾値に従い各画素の明暗を判定し、その明暗数から欠陥を判定する。



1

【特許請求の範囲】

【請求項1】明暗が所定のピッチPで規則性をもって連続するモアレ等の基準パターンを、そのまま又は欠陥のない正常な透明物体を透して固体撮像素子によるイメージセンサで受光し、その受光したパターンの明暗の画素数から上記ピッチPを検出した後、同じ基準パターンを検査対象の透明物体を透して同じイメージセンサで受光し、その画素データに対し、上記検出したピッチPを基準とする所定画素数だけ離れた2つの画素データの平均値から閾値を設定し、この閾値に従い各画素の明暗を判定し、その明暗数から欠陥を判定することを特徴とする透明物体の欠陥検査方法。

【請求項2】前記検出したピッチPの2分の1だけ離れた2つの画素データの平均値から閾値を設定することを特徴とする請求項1記載の透明物体の欠陥検査方法。

【請求項3】前記平均値に補正値を加えた値を上閾値、該補正値を差し引いた値を下閾値とし、各画素データがこれら上下の閾値の間のときは暗、それ以外のときは明と判定することを特徴とする請求項1又は2記載の欠陥検査方法。

【請求項4】上記上下の閾値による明暗判定後、さらに単位面積当たりの複数の画素群につき明暗それぞれの画素数を計数し、その差に従い各画素の明暗を決定することを特徴とする請求項1ないし3のいずれかに記載の透明物体の欠陥検査方法。

【請求項5】明暗が所定のピッチPで規則性をもって連続するモアレ等の基準パターンと、該基準パターンを透明物体を透して受光する固体撮像素子によるイメージセンサと、正常な透明物体を透し又はそのまま該イメージセンサによって受光された基準パターンの像の明暗の画素数から上記ピッチPを検出する基準パターンピッチ検出手段と、検査対象の透明物体を透して上記イメージセンサに受光された上記基準パターンの画素データについて、上記検出されたピッチPを基準とする所定画素数だけ離れた2つの画素データの平均値を算出する平均値算出手段と、その平均値から明暗判定レベルの上下の閾値を設定する閾値設定手段と、上記画素データが上記上下の閾値の間のときは暗、それ以外のときは明と判定することによって基準パターンによるデータを消去する基準パターン消去手段と、その消去後の画素データについて、単位面積当たりの複数の画素群につきその明暗それぞれの画素数を計数し、その差に従い各画素の明暗を決定する明暗決定手段と、その決定された明暗数により欠陥を判定する欠陥判定手段とを備えてなることを特徴とする透明物体の欠陥検査装置。

【発明の詳細な説明】

【0001】

【産業上の利用分野】本発明は、透明ガラス容器等の透明物体の欠陥の有無や形状や種類等を検査する方法及び装置に関する。なお、本発明で「透明」とはいわゆる「半透明」も含めて言うものとする。

2

【0002】

【従来の技術】特開平2－49148号公報には、びんの胴部を縞模様を形成するように照明し、その胴部の透過映像を二次元光電変換装置で光電変換し、光電変換された透過映像を上記縞模様の縞方向に対して斜め方向に走査し、その走査線上に近接する少なくとも3点の明るさを比較し、これら3点の内側に位置する注目点の明るさが両側の周辺点の明るさに対して所定値以上異なる場合に当該注目点を欠陥点として検出し、その検出された欠陥点に基づいて欠陥の有無を判定する、びんの胴部の検査方法が開示されている。

【0003】この従来例は、要するに、縞模様を例えば白黒の帯が交互に繰り返すパターンとした場合、びんに欠陥があれば、その遮光性又は屈折性により白部分に黒、黒部分に白の透過映像が連続して現れるのに対し、欠陥がなければそれが現れないか又は離散的に現れるということに立脚している。そして、所定距離離れたA・B・C3点のうちA点を注目点とした場合、A点とB点との間、及びA点とC点との間の明るさの差の絶対値が共に設定値を越えた場合に、A点を欠陥点とするものである。

【0004】

【発明が解決しようとする課題】しかし、これによると、異物や汚れ等の遮光性欠陥、及び泡、すじ、しわ等の屈折性欠陥の有る無しは検出できるが、その種類や形状までは判別することができない。また、小さい欠陥については画像処理上、その有無の判定も難しい。欠陥は、ガラスそのものに起因するものと成形に起因するものに大別されるが、欠陥の種類及び形状を判別できれば、その発生原因や発生過程などが分かるため、その防止策を容易にかつ早急に採れるので、製品の品質の安定化を図る上で非常に重要なことである。

【0005】本発明の目的は、遮光性の欠陥及び屈折性の欠陥のいずれについても、その有無は勿論のこと、その形状や種類までも判別することができ、しかも欠陥が小さくともその判別を精度良く行える透明物体の欠陥検査方法及び装置を提供することである。

【0006】

【課題を解決するための手段】本発明による欠陥検査方法は、明暗が所定のピッチPで規則性をもって連続するモアレ等の基準パターンを、そのまま又は欠陥のない正常な透明物体を透して固体撮像素子によるイメージセンサで受光し、その受光したパターンの明暗の画素数から上記ピッチPを検出した後、同じ基準パターンを検査対象の透明物体を透して同じイメージセンサで受光し、その画素データに対し、上記検出したピッチPを基準とする所定画素数だけ離れた画素データの平均値から閾値を設定し、この閾値に従い各画素の明暗を判定し、その明暗数から欠陥を判定する。

3

【0007】上記平均値は、検出したピッチPの2分の1だけ離れた2つの画素データから求めることが望ましい。その平均値に補正値を加えた値を上閾値、該補正値を差し引いた値を下閾値とし、各画素データがこれら上下の閾値の間のときは暗、それ以外のときは明と判定すると良く、さらにその後、単位面積当たりの複数の画素群につき明暗それぞれの画素数を計数し、その差に従い各画素の明暗を決定すると一層良い。

【0008】本発明による欠陥検査装置は次のような手段よりなる。

① 明暗が所定のピッチPで規則性をもって連続するモアレ等の基準パターン

② 該基準パターンを透明物体を透して受光する固体撮像素子によるイメージセンサ

③ 正常な透明物体を透し又はそのまま疎イメージセンサによって受光された基準パターンの像の明暗の画素数から上記ピッチPを検出する基準パターンピッチ検出手段

④ 検査対象の透明物体を透してイメージセンサに受光された基準パターンの画素データについて、上記ピッチPを基準とする所定画素数だけ離れた2つの画素データの平均値を算出する平均値算出手段

⑤ その平均値から明暗判定レベルの上下の閾値を設定する閾値設定手段

⑥ 画素データが上下の閾値の間のときは暗、それ以外のときは明と判定することによって基準パターンによるデータを消去する基準パターン消去手段

⑦ その消去後の画素データについて、単位面積当たりの複数の画素群につきその明暗それぞれの画素数を計数し、その差に従い各画素の明暗を決定する明暗決定手段

⑧ その決定された明暗数により欠陥を判定する欠陥判定手段

【0009】

【作用】本発明の欠陥検出の基本思想は、明暗が所定のピッチPで規則性をもって連続するモアレ等の基準パターンを透明物体を透して撮影した場合、欠陥のない透明物体ではその基準パターンの規則性が損なわれないの対し（図5参照）、欠陥のある透明物体では、その欠陥が歪光性及び屈折性のいずれであっても、規則性が損なわれる（図6参照）、ということに立脚している。従って、本発明で言う基準パターンのピッチPは検出しようとする欠陥の大きさに比べて小さく設定される。この点に関し上述した従来例では、縞模様の帯の太さ及びピッチを比較的大きくしないと画像処理が難しく、それだけ小さい欠陥に対する精度が落ちることになる。

【0010】本発明では、基準パターンをそのまま又は欠陥のない正常な透明物体を透して撮影することにより得られたデータから、基準パターンのピッチPを検出する。そして、検査対象の透明物体を透して基準パターンを撮影した画素データの明暗判定を行うに当たり、基準

4

パターンのピッチPの例えば2分の1離れた2つの画素データの平均値を求め、この値から明暗判定の閾値を設定する。画素データの明暗が基準パターン通りであれば、そのピッチの2分の1だけズレた2つの画素のデータの平均値は、イメージセンサの入光光量の変化などに影響されることなく一定である。この求めた平均値から閾値を設定する。例えば、平均値に、予め決めた補正値を加えた値を上閾値、該補正値を差し引いた値を下閾値とする。

【0011】そして、各画素データをこれら上下の閾値に従い2値化し、上下の閾値の間のときは「0」（すなわち暗）、それ以外のときは「1」（すなわち明）とすれば、基準パターン通りに明暗が規則的になっている画素群についてはほとんど「1」となるので、その暗部分の大半が消去される。つまり、画素データのなかの基準パターンの明暗による要素がほとんど除去されるのに対し、欠陥によりパターンが欠如した又はランダムになった部分は残ることになる。この後、さらにフィルタリング、つまりある画素の明暗（1か0か）を最終的に決定するに当たり、その周囲の単位面積当たりの複数の画素群につきその明暗それぞれの画素数を計数し、「1」（明）の画素数が過半数以上であれば、その単位面積の平均の明るさは明であるため、当該画素自体は「0」（暗）であっても、それを「1」（明）とする。逆に、「0」（暗）の画素数が過半数以上であれば、その単位面積の平均の明るさは暗であるため、当該画素自体は「1」（明）であっても、それを「0」（暗）とする。このようなフィルタリングを行うと、欠陥により暗となった画素だけ抽出され、その画素を例えば計数することにより欠陥の有無、さらにその形状や種類を容易に判定することができる。

【0012】

【実施例】以下、本発明の実施例について説明する。図2に本発明の方法の一例の概念を示す。この例では、基準パターン1を拡散ストロボ光源2で照明し、これを、コンベア3で検査位置に搬送されてきた検査対象の透明物体（例えば透明なガラスコップ）4の胴部を透して二次元のCCDカメラ5で撮影し、その撮影データを、拡散ストロボ光源2の発光と同期してCPUやRAMやROM等を含む画像処理装置6に取り込み、該画像処理装置6で画像処理して透明物体4の欠陥を検査する。図3は基準パターン1の一例を示し、幅W1の明部分7と幅W2の暗部分8とが一定のピッチPで交互に平行に並んだ斜めのモアレになっている。例えばW1は0．8㎜、W2は0．5㎜、Pは1．3㎜である。また本例では、図4に示すように透明物体4に対する検査範囲θを、その曲率による屈折光の影響を少なくするため、及びCCDカメラ5の視野の関係から透明物体4の胴部を大体60度ずつ3回に分けて検査する。

【0013】図5に欠陥のない透明物体4の場合におけ

5

る光路、図６に屈折性の欠陥部分９がある透明物体４の場合における光路を示す。図５の場合には、基準パターン１の明暗７，８による光線は透明物体４を真っ直ぐ透過し、ＣＣＤカメラ５においてレンズ１０により集光され、基準パターン１に対応した、すなわち明部分１２と暗部分１３とが基準パターン１の規則性と同様の幅、ピッチ及び傾斜をもって整列したモアレ像としてＣＣＤ型の二次元イメージセンサ１１（エリアセンサ）に受光される。これに対し第６図の場合には、欠陥部分９においても光線が屈折されるため、二次元イメージセンサ１１に受光された像は、欠陥部分９に対応する部分で明部分１２と暗部分１３との規則性がくずれ、その幅とピッチと傾斜が基準パターン１とは対応しないものとなる。欠陥部分９が遮光性の場合も同様である。

【００１４】イメージセンサ１１で受光された基準パターン１の像が図７の如くであった場合、イメージセンサ１１の出力を例えば直線Ｉ－Ｉに沿った画素（受光素子）について取り出すと、明部分１２と暗部分１３との規則性が保たれている部分では、その出力信号はほぼ正弦波に近い波形で表され、規則性が損なわれている部分、例えば図のように暗部分１３が続いている部分では信号波が欠落する。図８から図１１はイメージセンサ１１の画素出力を横一列（水平）に取り出したときの波形図で、図８は透明物体４に欠陥がなく基準パターン１通りの像が得られた場合で、一定ピッチＰで繰り返す正弦波となっている。図９、図１０、図１１はいずれも欠陥がある場合で、図９は欠陥のためにピッチが小さくなった場合、図１０はピッチが大きくなった場合、図１１は波が欠落した場合である。

【００１５】図１に画像処理装置６の概要構成を示し、ＣＰＵによって管理される機能によってその構成を分けたもので、この画像処理装置６はアナログ／デジタルコンバータ１４とメモリ１５と基準パターンピッチ・方向検出手段１６と平均値算出手段１７と閾値設定手段１８と基準パターン消去手段１９と明暗決定手段２０と欠陥判定手段２１とで構成される。二次元イメージセンサ１１の出力はアナログ／デジタルコンバータ１４によりデジタルデータに変換され後、各画素ごとにメモリ１５に記憶される。

【００１６】先ず、基準パターン１のピッチＰを検出するため、該基準パターン１をそのまま又は欠陥のない透明物体を透してＣＣＤカメラ５で撮影する。この場合、ＣＣＤカメラ５のイメージセンサ１１に受光される像は上記のように基準パターン１の規則性に対応したものとなり、取り出される信号波形は正弦波で表される。基準パターンピッチ・方向検出手段１６は、この正弦波の繰り返し周期に相当する画素数をもって基準パターン１のピッチＰを検出するとともに、その傾斜の方向も検出する。図１２にその正弦波を基準とした画像処理の手法を示す。なお、この画像処理は、実際には、イメージセンサ１１から取り出されてメモリ１５に記憶された各画素ごとのデジタルデータを読み出してデジタル処理で行われるものであるが、説明の便宜上、図１２の波形をもってアナログ的に説明する。

6

【００１７】基準パターンピッチ・方向検出手段１６で基準パターン１のピッチＰ及び傾斜方向を検出した後、検査対象の透明物体４をコンベア３で検査位置へ搬送し、基準パターン１を該透明物体４を透してＣＣＤカメラ５で撮影する。その撮影により得られたイメージセンサ１１からのデータは各画素ごとにメモリ１５に記憶される。平均値算出手段１７は、検出された基準パターン１のピッチＰ（正弦波の位相にして３６０度）及び傾斜方向を参照し、その２分の１のピッチ、つまりＰ／２だけ位相（１８０度）がズレた２点の画素データを取り出し、これを明暗それぞれにつき複数個所について行い、明部分の平均値（複数個所の明部分の最大輝度の平均値）と暗部分の平均値（複数個所の暗部分の最小輝度の平均値）をそれぞれ算出する。いま、図１２において基準パターン１が存在する部分につきＰ／２だけ離れたａ点の値をＨａ、ｂ点の値をＨｂとすると、平均値は（Ｈａ＋Ｈｂ）／２となる。また、基準パターン１が存在しない又はそのパターンが乱れいる部分につきＰ／２だけ離れたｃ点の値をＨｃ、ｄ点の値をＨｄとすると、平均値は（Ｈｃ＋Ｈｄ）／２となる。なお、平均値を求めるピッチは基準パターン１のピッチＰの２分の１にするのが好ましいが、これに限られるものではない。

【００１８】閾値設定手段１８は、平均値算出手段１７で求められた平均値（Ｈａ＋Ｈｂ）／２又は（Ｈｃ＋Ｈｄ）／２に予め決めた所定の補正値αを加えることにより、上閾値ＵＴＨ＝（Ｈａ＋Ｈｂ）／２＋α又はＵＴＨ＝（Ｈｃ＋Ｈｄ）／２＋αを設定するとともに、平均値（Ｈａ＋Ｈｂ）／２又は（Ｈｃ＋Ｈｄ）／２から補正値αを差し引くことによより、下閾値ＬＴＨ＝（Ｈａ＋Ｈｂ）／２－α又はＬＴＨ＝（Ｈｃ＋Ｈｄ）／２－αを設定する。

【００１９】基準パターン消去手段１９は、メモリ１５に記憶された各画素データを上閾値ＵＴＨ及び下閾値ＬＴＨと比較し、図１２に示すように、当該画素データが上下の閾値ＵＴＨとＬＴＨの間のときは「０」（すなわち暗）、それ以外のときは「１」（すなわち明）として２値化する（同図の下側に２値化信号として表す）。このような２値化処理により、基準パターン１通りに明暗が水平方向に規則的になっている画素群はほとんど「１」と判定されるため、基準パターン１の暗部分の大半が消去される。つまり、基準パターンによる暗部分はほとんど除去されるのに対し、欠陥により基準パターンが欠如した暗部分（２値数で０）又はランダムになった暗部分は残ることになる。

【００２０】基準パターン消去手段１９による上記のような２値化によっても、図１２に示す如く、基準パター

ン1による規則性のある暗部分（2値数で0）が僅かず つ残るが、その残った暗部分の大きさ（0と判定された画素の連続個数）は、欠陥による暗部分に比べ小さい。そこで、明暗決定手段20は、基準パターン消去手段19による仮の2値化後に、さらに各画素の明暗（1か0か）を、周辺の複数の画素との関係から次のようなフィルタリング処理により最終的に決定する。図13及び図14にその手法を示す。いま、図13においてある1つの画素22が基準パターン消去手段19による2値化によって仮に「0」と判定されていたとする。この画素22について「1」か「0」かを最終的に決定するに当たり、この画素22にさらにその周囲の画素23も加えた単位面積当たりの画素群につき、「1」とされた画素の個数と、「0」とされた画素の個数をそれぞれ計数する。そして、その多い方の2値数をもって当該画素22の2値数を決定する。図の例の場合、「1」の画素数が過半数を越えているので、画素22を図14のように「0」から「1」に変更する。すなわち、単位面積当たりの画素群について、その平均の輝度を求め、決められた輝度以上ならば、その中心の画素を「1」（明）とする。このような処理により、基準パターン消去手段19で残った基準パターン1の暗部分は除去され、欠陥による暗部分だけが抽出される。

【0021】欠陥判定手段21は、明暗決定手段20による明暗決定後の画素について、「0」が続いている部分の画素数を水平方向及び垂直方向、あるいはさらに斜め方向に計数し、その値が所定以上のとき欠陥有りと判定して検査対象の透明物体4を排除する排除信号を出力する。また、その計数した画素数から欠陥の形状や種類を公知のパターン認識手法により判定する。

【0022】図15から図17は検査作業のそれぞれ異なる例を示す。図15の場合、第1の光源2a と第2のCCDカメラ5a，第2の光源2b と第2のCCDカメラ5b，第3の光源2c と第3のCCDカメラ5c の3組を、コンベア3の搬送方向（矢印方向）に離して配置し、その第1と第2の間、及び第2と第3の間に第1及び第2の2台の回転装置24を設置する。そして、第1のCCDカメラ5a により透明物体4の胴部の3分の1を撮影し、透明物体4を第1の回転装置24へ搬送して60度回転させた後、搬送して第2のCCDカメラ5b で次の3分の1を撮影し、次いで第2の回転装置24へ搬送してさらに60度回転させ、同様に搬送して第3のCCDカメラ5c で残りの3分の1を撮影する。なお、25はコンベア3の速度を検出する速度検出装置、26は、欠陥判定手段21により欠陥有りと判定された透明物体4をコンベア3上より排除する排除装置である。

【0023】図16の場合、第1組の光源2a 及びCCDカメラ5a と、第2組の光源2b 及びCCDカメラ5b とを、その光軸が60度の角度をなすように配置する一方、これより離して第3組の光源2c 及びCCDカメラ5c を配置し、第1組と第2組のCCDカメラ5a，5b で透明物体4の胴部をそれぞれ3分の1ずつ同一場所で撮影した後、透明物体4を回転装置24へ搬送して90度回転させ、第3組のCCDカメラ5c で残りの3分の1を撮影する。

【0024】図17の場合、3組の光源及びCCDカメラを60度の角度をなすように配置し、透明物体4の胴部をそれぞれ3分の1ずつ同一場所で撮影する。

【0025】以上、本発明の好適な実施例について説明したが、本発明はこれに限定されるものではない。基準パターン1は上記の実施例では斜めのモアレとしたが、図18のような格子模様でも良く、明暗が所定のピッチで規則的に連続しているものであれば良い。また、上閾値と下閾値の2つの閾値を設定したが、一つの閾値を基準として明暗の判定を行っても良い。上記の例では二次元CCDカメラ5を使用し、基準パターン1及び透明物体4を静止させた状態で検査したが、透明物体4を回転させながら検査しても良い。さらに、図19図に示すように一次元イメージセンサ（ラインセンサ）27を備えた一次元CCDカメラ28を使用し、円筒形の基準パターン30を光源30の回りで回転させると同時に、透明物体4を回転させる方法でも、上記と同様の処理により欠陥を検査できる。

【0026】

【発明の効果】本発明によれば、遮光性の欠陥及び屈折性の欠陥のいずれについても、その有無は勿論のこと、その形状や種類までも判別することができ、しかも欠陥が小さくともその判別を精度良く行える。

【図面の簡単な説明】

【図1】　本発明による透明物体の欠陥検査装置のブロック図である。

【図2】　本発明による方法の概念図である。

【図3】　基準パターンの一例の態様図である。

【図4】　透明物体の検査領域を示す説明図である。

【図5】　欠陥がない場合の光路図である。

【図6】　欠陥がある場合の光路図である。

【図7】　基準パターンの撮影像とイメージセンサの出力波形を対照して示す図である。

【図8】　欠陥がない場合の基準のピッチ通りの波形図である。

【図9】　欠陥により上記ピッチが小さくなった場合の波形図である。

【図10】　欠陥によりピッチが大きくなった場合の波形図である。

【図11】　欠陥により波が欠落した場合の波形図である。

【図12】　閾値設定及び2値化の手法を示す波形図である。

【図13】　フィルタリング処理の手法を説明する図である。

【図１４】　フィルタリング処理の手法を説明する図である。

【図１５】　検査作業を説明する平面図である。

【図１６】　検査作業の他の例を説明する平面図である。

【図１７】　検査作業の別の例を説明する平面図である。

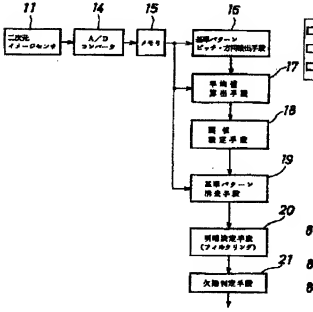
【図１８】　基準パターンの他の例を示す態様図である。

【図１９】　一次元ＣＣＤカメラを使用して検査する本発明の他の例の概念図である。

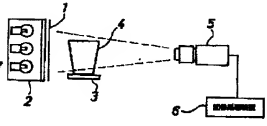
【符号の説明】

1	基準パターン
１１	二次元イメージセンサ
１６	基準パターンピッチ・方向検出手段
１７	平均値算出手段
１８	閾値設定手段
１９	基準パターン消去手段
２０	明暗決定手段
２１	欠陥判定手段

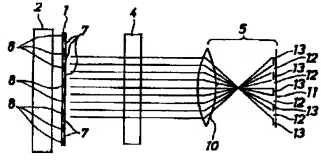
【図１】



【図２】



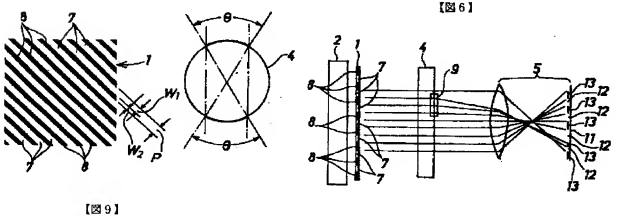
【図５】



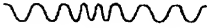
【図３】

【図４】

【図６】



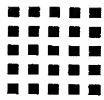
【図９】



【図７】

【図８】

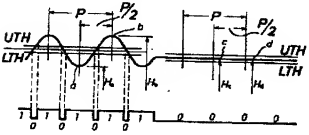
【図１８】



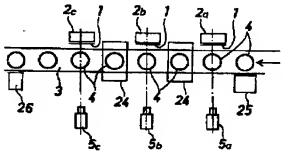
【図１０】

【図１１】

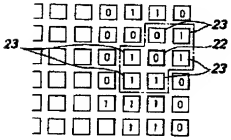
【図１２】



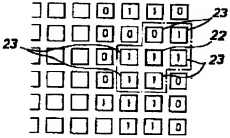
【図１５】



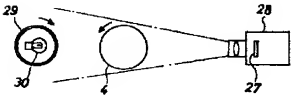
【図１３】



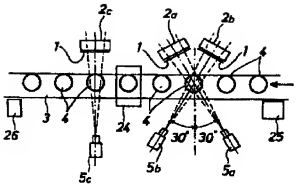
【図１４】



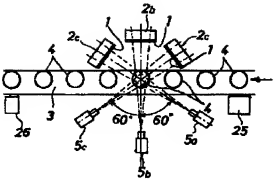
【図１９】



【図16】


2c
2a
2b
1
1
1
4
3
4
4
24
26
25
30°
30°
5c
5b
5a

【図17】


2b
1
1
2c
2c
1
4
4
3
4
26
25
60°
60°
5c
5a
5b

US005216481A

United States Patent [19]

Minato

[11] Patent Number: 5,216,481

[45] Date of Patent: Jun. 1, 1993

[54] **METHOD OF AND APPARATUS FOR INSPECTING TRANSPARENT OBJECT FOR DEFECT**

[75] Inventor: **Nobuhiro Minato**, Tokyo, Japan

[73] Assignee: **Toyo Glass Co., Ltd.**, Tokyo, Japan

[21] Appl. No.: **808,620**

[22] Filed: **Dec. 17, 1991**

[30] **Foreign Application Priority Data**

Dec. 19, 1990 [JP] Japan 2-411634

[51] **Int. Cl.**[5] **G01N 21/90**

[52] **U.S. Cl.** ..... **356/240**; 250/223 B

[58] **Field of Search** ..... 356/237, 239, 240, 426, 356/428; 250/223 B

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2-49148	2/1990	Japan .

Primary Examiner—Vincent P. McGraw
Attorney, Agent, or Firm—Sughrue, Mion, Zinn, Macpeak & Seas

[57] **ABSTRACT**

A method of and an apparatus for inspecting a transparent object for a defect wherein both of a light blocking defect and a refracting defect can be discriminated not only for presence or absence thereof but also for a shape and a kind thereof and besides discrimination of a small defect can be performed with a high degree of accuracy. According to the method, a pitch of strips of a reference striped pattern is detected in prior. Then, an object for inspection is placed at an inspecting position, and light having the reference pattern is projected upon the object and transmission light is photographed by an image sensor. A threshold value is set from an average value between two picture element data spaced from each other by one half the detected pitch, and the picture element data are successively compared with the threshold value to determine the bright or the dark thereof. A defect of the object is discriminated from numbers of picture elements determined as the bright and the dark.

12 Claims, 9 Drawing Sheets

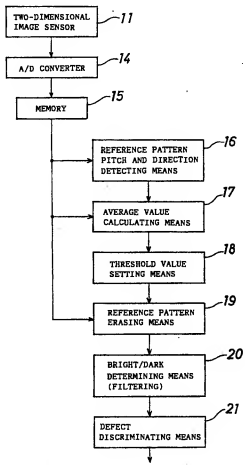


FIG.1

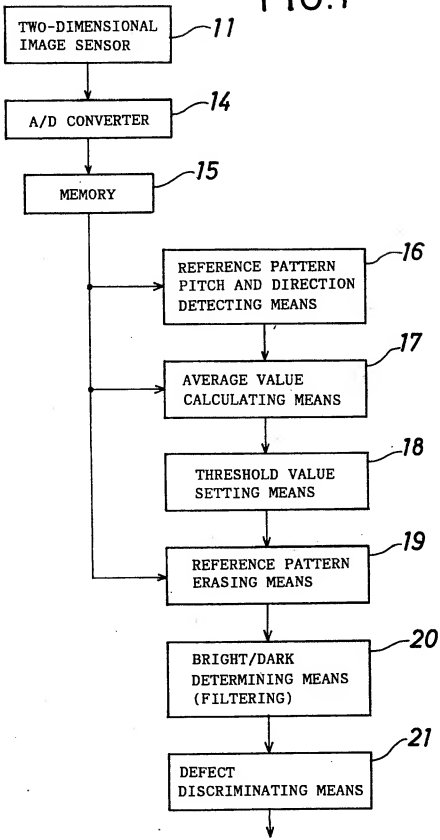

TWO-DIMENSIONAL IMAGE SENSOR
11
A/D CONVERTER
14
MEMORY
15
REFERENCE PATTERN PITCH AND DIRECTION DETECTING MEANS
16
AVERAGE VALUE CALCULATING MEANS
17
THRESHOLD VALUE SETTING MEANS
18
REFERENCE PATTERN ERASING MEANS
19
BRIGHT/DARK DETERMINING MEANS (FILTERING)
20
DEFECT DISCRIMINATING MEANS
21

FIG.2

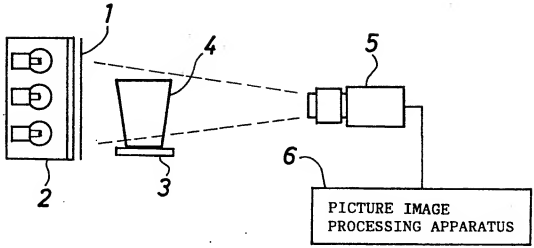


FIG.3

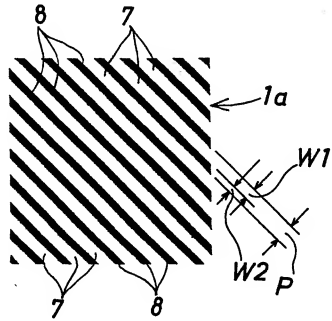


FIG.4

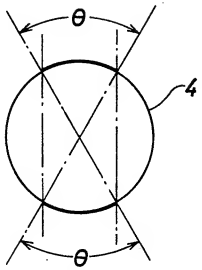


FIG.5

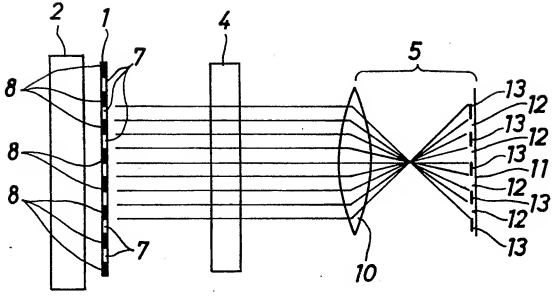


FIG.6

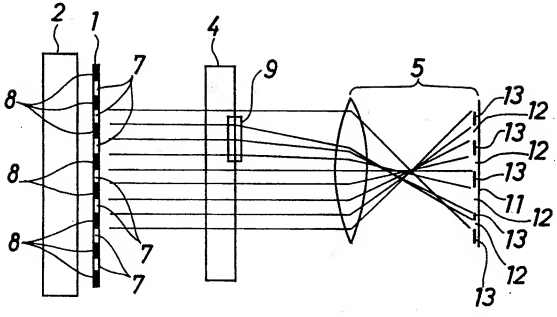


FIG.7

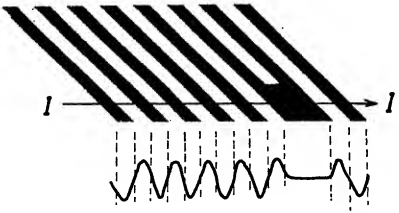


FIG. 8

FIG. 9

FIG. 10

FIG. 11

FIG. 12

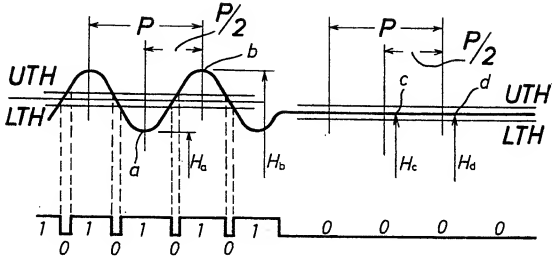

P
P/2
b
UTH
LTH
a
Ha
Hb
P
P/2
c
d
UTH
LTH
Hc
Hd
1 1 1 1 1 1 1 0 0 0 0
0 0 0 0 0

FIG. 15

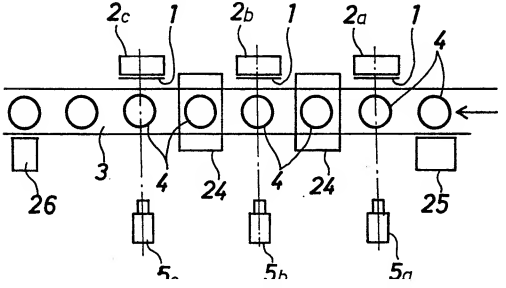

2c
1
2b
1
2a
1
4
3
4
24
4
24
26
25
5c
5b
5a

FIG.13

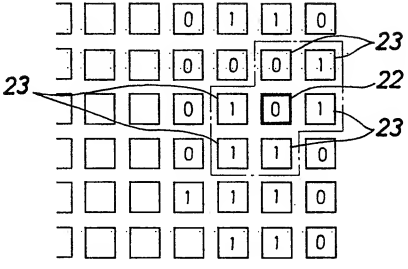


FIG.14

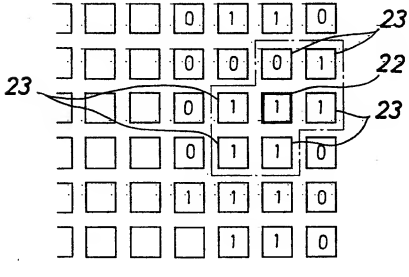


FIG. 16

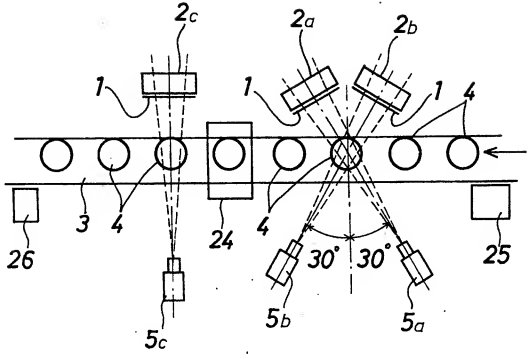

2c
2a
2b
1
1
1
4
3
4
4
24
26
30°
30°
25
5c
5b
5a

FIG. 17

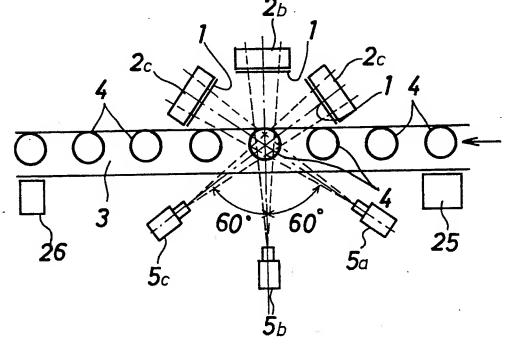

2b
1
1
2c
2c
4
1
4
3
4
60°
60°
26
25
5c
5a
5b

FIG.18

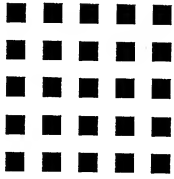
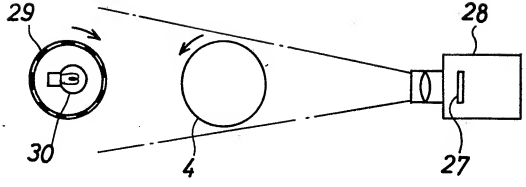


FIG.19



METHOD OF AND APPARATUS FOR INSPECTING TRANSPARENT OBJECT FOR DEFECT

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a method of and an apparatus for inspecting a transparent or translucent object such as a transparent glass vessel for presence or absence of a defect and a shape, a kind and so forth of such defect.

2. Description of the Prior Art

Various methods of inspecting a body of a bottle are already known, and an exemplary one of such conventional methods is disclosed, for example, in European Patent Application Publication No. 0 344 617. According to the method, a body of a bottle is illuminated with light having a striped pattern, and a transmission image of the body is photoelectrically converted by a two-dimensional photoelectric converting apparatus. Then, the transmission image signal is scanned in a direction oblique to the direction of stripes of the striped pattern, and brightness values at least at three points adjacent the scanning line are compared with each other. Then, a noted point which is a centrally positioned one of the three points is detected as a defect point when the brightness value at the noted point is different by an amount greater than a predetermined value from brightness at the other peripheral points on the opposite sides of the noted point, and then presence or absence of a defect is determined in accordance with the thus detected defect point.

The inspecting method is based in short on the fact that, where the striped pattern is, for example, a pattern wherein white and black stripes or bands repeat alternately, if a bottle has a defect, then either a black transmission image is successively produced in a white stripe or a white transmission image is successively produced in a black stripe, by a light blocking property or a refracting property of such defect, but on the contrary if a bottle has no defect, then no such image is produced or such images are produced but discretely. Where a point A among three points A, B and C which are spaced by a predetermined distance from each other is determined as a noted point, if both of absolute values of differences in brightness between the points A and B and between the points A and C exceed a preset value, then the point A is determined as a defect point.

However, according to the conventional inspecting method, while presence or absence of a light blocking defect such as a foreign article or a soil or a refracting defect such as a foam, a line or a wrinkle, a kind or a shape of such defect cannot be discriminated. Further, where the defect is small in size, even judgment of presence or absence of such defect is difficult by picture image processing. While defects are roughly divided into those which arise from glass itself and those which arise from shaping, if a kind and a shape of a defect can be determined, than a cause of production or a process of production of such defect can be recognized, and consequently, a countermeasure for preventing such defect can be taken readily and promptly. Therefore, it is very important to discriminate a kind and a shape of a defect in order to assure stabilization in quality of products.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a method of and an apparatus for inspecting a transparent or translucent object for a defect wherein both of a light blocking defect and a refracting defect can be discriminated not only for presence or absence thereof but also for a shape and a kind thereof.

It is another object of the present invention to provide a method of and an apparatus for inspecting a transparent or translucent object for a defect wherein, even if a defect is small, discrimination of it can be performed with a high degree of accuracy.

In order to attain the objects, according to one aspect of the present invention, there is provided a method of inspecting a transparent or translucent object for a defect, which comprises the steps of projecting light having a reference pattern such as a moire wherein bright and dark portions appear successively and regularly at a predetermined pitch, receiving the pattern light directly or by way of a defect-free normal transparent article by an image sensor in the form of a solid-state image pickup element, detecting the pitch of the reference pattern of the light from numbers of picture elements of bright and dark portions of the light pattern received by the image sensor, placing an object at an inspecting position on a path of projected pattern light, projecting light having the reference pattern upon the object at the inspecting position so that light transmitted through the object may be received by the image sensor, storing data of picture elements from the image sensor into a memory, setting a threshold value from an average value between two picture element data from the memory spaced from each other by a distance corresponding to a predetermined number of picture elements with reference to the detected pitch, comparing each of the picture element data from the memory with the threshold value to determine the bright or the dark of the picture element data, discriminating a defect of the object from numbers of picture elements determined as the bright and the dark, and removing, after any step after the second light projecting step, the object from the inspecting position.

Preferably, the threshold value is determined from an average value between data of two picture element spaced from each other by a distance equal to one half the detected pitch. Preferably, at the setting step, a value obtained by adding a correction value to the average value is set as an upper threshold value while another value obtained by subtracting the correction value from the average value is set as a lower threshold value, and at the comparing step, each of the picture element data is successively compared with the upper and lower threshold values and when it falls between the upper and lower threshold values, it is determined as the dark, but in any other case, it is determined as the bright. In this instance, preferably, at the setting step, after determination of each of the picture element data between the bright and the dark with reference to the upper and lower threshold values, a number of picture elements in a unit area around the picture element is counted for each of the bright and the dark, and the bright or the dark of the picture element is determined in accordance with a difference between the numbers of the picture elements for the bright and the dark.

In accordance with the present invention, detection of a defect is principally based on the fact that, when a reference pattern such as a moire wherein the bright

and the dark appear successively and regularly at a predetermined pitch is photographed through a transparent or translucent object, if the transparent or translucent object is free from a defect, the regularity of the reference pattern is maintained with the thus photographed image, but on the contrary if the transparent or translucent object has a defect, whether the defect is a light blocking defect or a refracting defect, the regularity of the reference pattern is damaged or lost. Accordingly, the pitch of the reference pattern is set to a small value comparing with a size of a defect to be detected. In this connection, with the conventional inspecting method described hereinabove, image processing is difficult unless the width and the pitch of stripes of the striped pattern are set to comparatively great values, and the accuracy in detection of a defect of a small size is deteriorated accordingly.

Thus, according to the method, a pitch of a reference pattern is detected from data obtained by photographing the reference pattern directly or through a defect-free normal transparent article. Then, the reference pattern is photographed through an object for inspection in the form of a transparent or translucent object to obtain picture element data, and the picture element data thus obtained are stored into a memory and individually judged between the bright and the dark. In this instance, an average value between data of two picture elements spaced from each other by a distance, for example, equal to one half the pitch of the reference pattern is calculated first, and a threshold value for judgment between the bright and the dark is set. If the distribution of the bright and dark of the picture element data coincides with that of the reference pattern, then the average value of the data of the two picture elements spaced by one half the pitch of the reference pattern is constant without being influenced by a variation in amount of incidence light to the image sensor. Thus, a threshold value is set from the thus calculated average value. In this instance, a predetermined correction value may be added to and subtract from the average value to obtain an upper threshold value and a lower threshold value, respectively.

Then, each of the picture element data from the memory may be compared with such upper and lower threshold values to binary digitize it such that, when it falls between the upper and lower threshold values, it is determined as "0" (that is, dark), but in any other case, it is determined as "1" (that is, bright). As a result of such binary digitization, picture elements in a portion wherein the bright and the dark appear regularly conforming to the reference pattern are almost discriminated as "1", and consequently, almost all of the dark portions are erased. In short, while elements of the picture element data which arise from the bright and the dark of the reference pattern are almost removed, the other elements where the reference pattern drops or the reference pattern appears at random due to presence of a defect will remain. After then, each of the picture elements is finally determined between the bright and the dark ("1" and "0"). In this instance, picture elements in a unit area around the picture element are taken, and a number of such picture elements is counted for each of the bright and the dark. Then, if the number of picture elements determined to be "1" (the bright) is greater than the number of the other picture elements determined to be "0" (the dark), then the average brightness in the unit area is the bright, and consequently, the picture element is finally determined as "1" (the bright) even if it is originally determined as "0" (the dark). On the contrary, if the number of picture elements determined to be "0" (the dark) is greater, then since the average brightness in the unit area is the dark, the picture element is determined as "0" (the dark) even if it is originally determined as "1" (the bright). As a result of such filtering, only those picture elements which are made the dark by a defect are extracted. Finally, the number or such picture elements is counted. Thus, from a result of such counting, presence or absence of a defect and, when a defect is present, a shape and a type of such defect, can be discriminated readily.

Thus, with the inspecting method of the present invention, when a transparent or translucent object has a defect, whether the defect is of the light blocking type or of the refracting type, not only presence of such defect but also a shape and a kind can be discriminated. Besides, even if the defect is small in size, it can be discriminated with a high degree of accuracy.

According to another aspect of the present invention, the method is accomplished with an apparatus for inspecting a transparent or translucent object for a defect, which comprises a reference pattern carrier having thereon a reference pattern such as a moire wherein the bright and the dark appear successively and regularly at a predetermined pitch, a light source for irradiating light upon the reference pattern carrier, an image sensor in the form of a solid-state image pickup element for receiving light of the reference pattern transmitted through the reference pattern carrier, memory means for receiving and storing therein data of picture elements from the image sensor, reference pattern pitch detecting means for detecting the pitch of the reference pattern from numbers of picture element data of the bright and the dark from the memory means which have been obtained from an image of the reference pattern received directly or by way of a normal transparent article by the image sensor, average value calculating means for calculating an average value between those two of the picture element data of the reference pattern from the memory means obtained from an image of the reference pattern received through an object by the image sensor which are spaced by a predetermined number of picture elements with reference to the pitch detected by the reference pattern pitch detecting means, threshold value setting means for setting upper and lower threshold values from the average value, reference pattern erasing means for successively comparing the picture element data from the memory means with the upper and lower threshold values to determine the picture element data as the dark when the picture element data fall between the upper and lower threshold values but determine the picture element data as the bright in any other case to erase data based on the reference pattern, bright/dark determining means for counting numbers of data of those picture elements in a unit area around each of the picture elements which are determined as the bright and the dark and determining the bright or the dark of the picture element in accordance with a difference between the thus counted numbers, and defect discriminating means for discriminating a defect from numbers of data of picture elements of the bright and the dark determined by the bright/dark determining means.

Thus, with the inspecting apparatus, whether a defect of a transparent or translucent object is of the light blocking type or of the refracting type, not only presence of such defect but also a shape and a kind can be

discriminated. Besides, even if the defect is small in size, it can be discriminated with a high degree of accuracy.

The above and other objects, features and advantages of the present invention will become apparent from the following description and the appended claims, taken in conjunction with the accompanying drawings in which like parts or elements are denoted by like reference characters.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of an apparatus for inspecting a transparent object for a defect according to the present invention;

FIG. **2** is a diagrammatic representation illustrating inspection of a transparent object in accordance with an inspecting method of the present invention;

FIG. **3** is an illustrative view showing a reference pattern for use with the inspecting method;

FIG. **4** is a diagrammatic view showing an inspection area of a transparent object upon inspection in accordance with the inspecting method;

FIG. **5** is a diagrammatic representation showing a path of light when there is no defect on a transparent object upon inspection;

FIG. **6** is a similar view but showing a path of light when there is a defect on a transparent object;

FIG. **7** is a view showing a photographed image of a reference pattern and an output waveform of an image sensor of the apparatus of FIG. **1** in contrast;

FIG. **8** is a waveform diagram showing an output waveform of the image sensor when there is no defect on a transparent object and the output waveform presents a pitch conforming to a reference pitch;

FIG. **9** is a similar view but showing an output waveform of the image sensor when there is a defect on a transparent object and the output waveform presents a pitch decreased by such defect;

FIG. **10** is a similar view but showing an output waveform of the image sensor when there is a defect on a transparent object and the output waveform presents a pitch increased by such defect;

FIG. **11** is a similar view but showing an output waveform of the image sensor when there is a defect on a transparent object and the output waveform presents a portion from which a wave or waves are dropped by such defect;

FIG. **12** is a waveform diagram illustrating a method of setting a threshold value and binary digitization in accordance with the inspecting method;

FIG. **13** is a diagrammatic representation illustrating a technique of filtering processing in accordance with the inspecting method;

FIG. **14** is a view illustrating an alternative technique of filtering processing;

FIG. **15** is a schematic plan view illustrating an inspecting operation with an inspecting equipment in which the inspecting apparatus shown in FIG. **1** is incorporated;

FIG. **16** is a similar view illustrating another inspecting operation with a modified inspecting equipment;

FIG. **17** is a similar view illustrating a further inspecting operation with another modified inspecting equipment;

FIG. **18** is an illustrative view showing an alternative reference pattern for use with the inspecting method; and

FIG. **19** is a diagrammatic view illustrating alternative inspection in accordance with the present invention wherein an inspection is performed using a one-dimensional CCD camera.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring first to FIG. **2**, there is illustrated a manner in which a transparent or translucent object is inspected in accordance with a method of the present invention. According to the method, a reference pattern carrier **1** carrying a reference pattern thereon is illuminated by a diffusing flashlight emitting light source **2** and photographed with a two-dimensional CCD (charge coupled device) camera **5** through a body portion of a transparent or translucent object **4** such as, for example, a transparent glass transported to an inspecting position by a conveyor **3**. Such photograph data are fetched into a picture image processing apparatus **6** in a timed relationship to emission of light of the diffusing flashlight emitting light source **2** and image processed by the picture image processing apparatus **6** to inspect the transparent object **4** for a defect. The picture image processing apparatus **6** includes a CPU (central processing unit), a RAM (random access memory), a ROM (read only memory) and so forth not shown.

FIG. **3** shows an example of a reference pattern which may be carried by the reference pattern carrier **1**. The reference pattern **1***a* shown is an oblique moire wherein bright zones or stripes **7** having a width W1 and dark zones or stripes **8** having another width W2 are disposed alternately at a fixed pitch P and extend in parallel to each other. The dimensions of the widths W1 and W2 and the pitch P may be, for example, W1=0.8 mm, W2=0.5 mm, and P=1.3 mm.

Further, in order to minimize an influence of refracted light caused by a curved profile of the transparent object **4** and due to a restricted field of view of the CCD camera **5**, a body portion of the transparent object **4** of an object for inspection is inspected by total of three times. In particular, referring to FIG. **4**, in each inspecting operation, the body portion of the transparent object **4** is inspected only within a predetermined inspection range θ thereof, that is, the two-dimensional CCD camera **5** receives and photographs with light passing through diametrical arcuate portions of the body portion of the transparent object **4** which extend over almost 60 degrees around a center axis of the transparent object **4**. After each of the first and second inspecting operations is completed, the transparent object **4** is angularly rotated by almost 60 degrees to allow different diametrical arcuate portions of the body portion of the transparent object **4** to be inspected subsequently for the predetermined inspection range θ.

When the transparent object **4** has no defect at the body portion thereof being inspected, light from the diffusing flashlight emitting light source **2** follows such a light path as illustrated in FIG. **5**, but when it has, for example, such a refractive defective portion **9** as seen in FIG. **6**, light may follow such a light path as illustrated in FIG. **6**. In particular, referring to FIG. **5**, when the transparent object **4** has no defect, rays of light having a pattern based on the bright stripes **7** and the dark stripes **8** of the reference pattern of the reference pattern carrier **1** pass straightforwardly through the transparent object **4** and are condensed by a lens **10** of the CCD camera **5** so that they are received as a moire image corresponding to the reference pattern of the reference pattern carrier **1**; that is, having bright portions or stripes **12** and dark portions or stripes **13** which

are arranged in a row with a similar width, pitch and inclination conforming to the regularity of the reference pattern of the reference pattern carrier **1** by a two-dimensional image sensor **11** (area sensor) of the CCD type. On the other hand, when the transparent object **4** has such a refractive defective portion **9** as seen in FIG. **6**, rays of light are refracted by the defective portion **9**, and consequently, an image received by the two-dimensional image sensor **11** has no regularity of the bright portions **12** and dark portions **13** at a portion thereof corresponding to the defective portion **9** so that the width, pitch and inclination thereof do not correspond to those of the reference pattern of the reference pattern carrier **1**. This similarly applies to the case wherein the defective portion **9** is of the light blocking type.

In case an image of the reference pattern of the reference pattern carrier **1** received by the image sensor **11** is such as shown in FIG. **7**, if an output of the image sensor **11** is taken out from picture elements (light receiving elements), for example, along a straight line I—I, then at a portion where the regularity of the bright portions **12** and dark portions **13** is maintained, the output presents a waveform substantially similar to a sine wave, but at another particular portion where the regularity fails, for example at such a portion where, the dark portions **13** appear successively as shown in FIG. **7**, a signal wave drops at such particular portion from the sine waveform. FIGS. **8** to **11** are waveform diagrams when picture element outputs of the image sensor **11** are taken out along a transverse (horizontal) row or line. In particular, FIG. **8** shows a waveform when the transparent object **4** has no defect and an image conforming to the reference pattern of the reference pattern carrier **1** is obtained. The waveform presents a sine wave which repeats at a fixed pitch P. Each of FIGS. **9**, **10** and **11** shows a waveform when there is a defect, and FIG. **9** shows a waveform when the pitch is reduced due to presence of a defect; FIG. **10** shows a waveform when the pitch is increased due to presence of a defect; and FIG. **11** shows a waveform when a wave is absent.

A general construction of the picture image processing apparatus **6** is shown in FIG. **1**, wherein the construction is divided in accordance with functions to be controlled by the CPU. The picture image processing apparatus **6** includes an analog-to-digital (A/D) converter **14**, a memory **15**, reference pattern pitch and direction detecting means **16**, average value calculating means **17**, threshold value setting means **18**, reference pattern erasing means **19**, bright/dark determining means **20** and defect discriminating means **21**. An output of the two-dimensional image sensor **11** is first converted into digital data by the A/D converter **14** and then stored for each picture element into the memory **15**.

First, in order to detect a pitch P of the reference pattern of the reference pattern carrier **1**, the reference pattern is photographed directly or by way of a defect-free transparent article by the CCD camera **5**. In this instance, an image received by the image sensor **11** of the CCD camera **5** conforms to the regularity of the reference pattern of the reference pattern carrier **1** as described above and a waveform of a signal thus taken out presents a sine wave. The reference pattern pitch and direction detecting means **16** detects the pitch P of the reference pattern from a number of picture elements corresponding to a repeat period of the sine wave and also detects a direction of inclination of the reference pattern **1**. A technique of picture image processing with reference to such sine wave is illustrated in FIG. **12**. It is to be noted that, while the picture image processing is actually performed by digital processing of digital data for each picture element taken out from the image sensor **11** and stored into and read out from memory **15**, description thereof will be provided in an analog fashion with the waveform of FIG. **12** for the convenience of description.

After the pitch P and the inclination direction of the reference pattern are detected by the reference pattern pitch and direction detecting means **16**, transparent or translucent objects **4** as objects for inspection are transported successively and stepwise by the conveyor **3** to the inspection position. At the inspecting position, the reference pattern **1** is photographed through a transparent object **4** by the image sensor **11**. Data obtained from the image sensor **11** by such photographing are stored for each picture element into the memory **15**. The average value calculating means **17** refers to the detected pitch P (360 degrees in phase of the sine wave) and inclination direction of the reference pattern, takes out picture element data of two points displaced by the one half pitch, in short, by P/2, in phase (180 degrees) from each other, repeats this for a plurality of locations for the bright and dark portions or stripes, and calculates an average value among picture element data from the bright portions (average value among maximum brightness values from the bright portions) and an average value among the dark portions (average value among minimum brightness values from the plurality of dark portions). Now, where brightness values at points a and b spaced by P/2 from each other in a portion in which the reference pattern is exists in FIG. **12** are represented by Ha and Hb, respectively, then an average value is given by (Ha+Hb)/2. Meanwhile, where brightness values at points c and d spaced by P/2 in another portion in which the reference pattern does not exist or the reference pattern is out of order are represented by Hc and Hd, respectively, an average value is given by (Hc+Hd)/2. It is to be noted that, while the pitch for the calculation of an average value is preferably set to one half the pitch P of the reference pattern, it need not set to such specific value.

The threshold value setting means **18** adds a predetermined correction value α to the average value (Ha+Hb)/2 or (Hc+Hd)/2 calculated by the average value calculating means **17** to set an upper threshold value UTH=(Ha+Hb)/2+α or UTH=(Hc+Hd)/2+α and subtracts the correction value α from the average value (Ha+Hb)/2 or (Hc+Hd)/2 to set a lower threshold value LTH=(Ha+Hb)/2−α or LTH=(Hc+Hd)/2−α.

The reference pattern erasing means **19** compares each of the picture element data stored in the memory **15** with the upper threshold value UTH and lower threshold value LTH to binary digitize the picture element data such that, when the picture element data fall between the upper and lower threshold values UTH and LTH, they are represented as "0" (that is, dark), but in any other case, the picture element data are represented as "1" (that is, bright) as shown in FIG. **12** (such binary digitized signals are shown at a lower portion of FIG. **12**).

Picture elements in a portion wherein bright and dark portions or stripes appear regularly in a horizontal direction conforming to the reference pattern of the reference pattern carrier **1** as a result of such binary digitizing processing are almost discriminated as "1", and

consequently, almost all of the dark portions of the reference pattern **1** are erased. In short, while the dark portions provided by the reference pattern are almost removed, a dark portion (0 in binary number) where the reference pattern drops or another dark portion where the reference pattern appears at random due to presence of a defect will remain.

While dark portions (0 in binary number) having such regularity as originating from the reference pattern of the reference pattern carrier **1** will remain a little as shown in FIG. **12** even by such binary digitization by the reference pattern erasing means **19** as described above, the size of the remaining dark portions (consecutive number of picture elements for which a brightness value is discriminated as 0) is smaller than the size of dark portions originating from a defect. Thus, the bright/dark determining means **20** finally determines, after temporary binary digitization by the reference pattern erasing means **19**, the bright or the dark for each picture element by such filtering processing as described below from a relationship to a plurality of picture elements therearound. Different techniques of such filtering are illustrated in FIGS. **13** and **14**.

Referring now to FIG. **13**, it is assumed that a certain picture element **22** is discriminated temporarily as "0" as a result of binary digitization by the reference pattern erasing means **19**. In finally determining whether the picture element **22** is "1" or "0", a number of those picture elements in a group of picture elements per unit area including the picture element **22** and picture elements **23** around the picture element **22** which are discriminated as "1" and another number of those picture elements of the group of picture elements which are discriminated as "0" are counted individually. Then, one of the binary values having a greater count number is determined as a binary value of the picture element **22**. In the case of the picture elements shown in FIG. **13**, the number of picture elements of "1" exceeds one half, and accordingly, the picture element **22** is changed from "0" to "1" as seen from FIG. **14**. In other words, an average brightness value is calculated for a group of picture elements for a unit area, and if it is higher than a predetermined brightness value, then the picture element at the center of the unit area is determined as "1" (bright). As a result of such processing, the dark portions of the reference pattern **1** remaining after processing by the reference pattern erasing means **19** are removed, and only dark portions arising from a defect are extracted.

The defect discriminating means **21** counts a number of picture elements at that portion of picture elements after determination between the bright and the dark by the bright/dark determining means **20** in which "0" appears successively in a horizontal direction and a vertical direction or further in an oblique direction, and when the count value is higher than a predetermined value, the defect discriminating means **21** discriminates that a defect is present and outputs an excluding signal for excluding the transparent object **4** as an object for inspection. Further, a shape or a kind of the defect is discriminated from the number of the thus counted picture elements in accordance with a known pattern recognizing technique.

FIGS. **15** and **17** show different manners of inspection and different inspecting equipments to which an inspecting method of the present invention is applied. Referring first to FIG. **15**, the inspecting equipment shown includes three sets of light sources and CCD cameras including a first light source **2***a* and a first CCD camera **5***a*, a second light source **2***b* and a second CCD camera **5***b*, and a third light source **2***c* and a third CCD camera **5***c*. The three sets are disposed in a spaced relationship from each other in a transporting direction of a conveyor **3**, that is, in the direction indicated by an arrow mark, and two (first and second) rotating apparatus **24** are installed between the first and seconds sets and between the second and third sets, respectively. One third of a body portion of a transparent or translucent object **4** is photographed by the first CCD camera **5***a*, and then the transparent object **4** is transported to the first rotating apparatus **24**, at which it is rotated by 60 degrees. Then, it is transported again to an inspecting position by the second set, at which a next one third of the transparent object **4** is photographed by the second CCD camera **5***b*. The transparent object **4** is then transported to the second rotating device **24** and rotated further by 60 degrees, whereafter it is transported to an inspecting position by the third set and a remaining one third of the transparent object **4** is photographed by the third CCD camera **5***c*. It is to be noted that reference numeral **25** denotes a velocity detecting apparatus for detecting a velocity of the conveyor **3**, and **26** denotes an excluding apparatus for excluding from the conveyor **3** a transparent object **4** which has been discriminated as having a defect by the defect discriminating means **21**.

In the case of the inspecting equipment of FIG. **16**, a first set of a light source **2***a* and a CCD camera **5***a* and a second set of a light source **2***b* and a CCD camera **5***b* are disposed such that optical axes of them may make an angle of 60 degrees and cross each other at an inspecting position on a conveyor **3** while a third set of a light source **2***c* and a CCD camera **5***c* is disposed in a spaced relationship from the first and second sets such that a different one third of a body portion of a transparent or translucent object **4** is first photographed at the inspecting position by each of the CCD cameras **5***a* and **5***b* of the first and second sets, and then the transparent object **4** is transported to and rotated by 90 degrees by a rotating apparatus **24**, whereafter the remaining one third of the transparent object **4** is photographed by the CCD camera **5***c* of the third set.

In case of the inspecting equipment shown in FIG. **17**, three sets of light sources and CCD cameras are disposed such that they may make an angle of 60 degrees between them so that a different one third of a body portion of a transparent of translucent object **4** may be photographed at a same inspecting position by each of them.

Having now fully described the invention, it will be apparent to one of ordinary skill in the art that many changes and modifications can be made thereto without departing from the spirit and scope of the invention as set forth herein. For example, while the reference pattern **1***a* of the reference pattern carrier **1** is an oblique moire in the inspecting apparatus described hereinabove with reference to FIG. **2**, it may otherwise be such a pattern similar to a checker board pattern as shown in FIG. **18** or may be any pattern wherein the bright and the dark appear successively and regularly at a predetermined pitch. Further, while two threshold values including an upper threshold value and a lower threshold value are employed, discrimination between the bright and the dark may be performed with reference to a single threshold value. Furthermore, while the two-dimensional CCD camera **5** is used and an inspecting

operation is performed in a condition wherein each of reference pattern carrier **1** having the reference pattern and a transparent or translucent object **4** is left fixed, an inspecting operation may be performed while a transparent or translucent object **4** is being rotated. Further, an inspecting operation for a defect can be performed by the similar processing to that described above but in a different manner wherein, using a one-dimensional CCD camera **28** including a one-dimensional image sensor (line sensor) **27** as shown in FIG. **19**, a tubular reference pattern carrier **30** having a reference pattern thereon is rotated around a light source **30** while at the same time a transparent or translucent object **4** is rotated.

What is claimed is:

1. A method of inspecting a transparent or translucent object for a defect, comprising the steps of:

projecting light having a reference pattern such as a moire wherein bright and dark portions appear successively and regularly at a predetermined pitch;

receiving the pattern light directly or by way of a defect-free normal transparent article by an image sensor in the form of a solid-state image pickup element;

detecting the pitch of the reference pattern of the light from numbers of picture elements of bright and dark portions of the light pattern received by said image sensor;

placing an object at an inspecting position on a path of projected pattern light;

projecting light having the reference pattern upon the object at the inspecting position so that light transmitted through the object may be received by said image sensor;

storing data of picture elements from said image sensor into a memory;

setting a threshold value from an average value between two picture element data from said memory spaced from each other by a distance corresponding to a predetermined number of picture elements with reference to the detected pitch;

comparing each of the picture element data from said memory with the threshold value to determine the bright or the dark of the picture element data;

discriminating a defect of the object from numbers of picture elements determined as the bright and the dark; and

removing, after any step after the second light projecting step, the object from the inspecting position.

2. A method as claimed in claim **1**, wherein the threshold value is determined from an average value between data of two picture elements spaced from each other by a distance equal to one half the detected pitch.

3. A method as claimed in claim **1**, wherein, at the setting step, a value obtained by adding a correction value to the average value is set as an upper threshold value while another value obtained by subtracting the correction value from the average value is set as a lower threshold value, and at the comparing step, each of the picture element data is successively compared with the upper and lower threshold values and when it falls between the upper and lower threshold values, it is determined as the dark, but in any other case, it is determined as the bright.

4. A method as claimed in claim **3**, wherein, at the setting step, after determination of each of the picture element data between the bright and the dark with reference to the upper and lower threshold values, a number of picture elements in a unit area around the picture element is counted for each of the bright and the dark, and the bright or the dark of the picture element is determined in accordance with a difference between the numbers of the picture elements for the bright and the dark.

5. A method as claimed in claim **1**, wherein, after the removing step, a new object is placed at the inspecting position and the steps from the second projecting step to the removing step are repeated to perform inspection of the new object for a defect.

6. A method as claimed in claim **1**, wherein, at the second light projecting step, light having the reference pattern is projected diametrically upon the object at the inspecting position over an angle of about 60 degrees around an axis of the object so that light transmitted through the object may be received by said image sensor, and further comprising the step of rotating, after the second light projecting step or after any step after then, the object around the axis thereof by 60 degrees twice, the steps from the storing step to the discriminating step being repeated after each rotation of the object by 60 degrees to perform inspection of the entire object for a defect.

7. An apparatus for inspecting a transparent or translucent object for a defect, comprising:

a reference pattern carrier having thereon a reference pattern such as a moire wherein the bright and the dark appear successively and regularly at a predetermined pitch;

a light source for irradiating light upon said reference pattern carrier;

an image sensor in the form of a solid-state image pickup element for receiving light of the reference pattern transmitted through said reference pattern carrier;

memory means for receiving and storing therein data of picture elements from said image sensor;

reference pattern pitch detecting means for detecting the pitch of the reference pattern from numbers of picture element data of the bright and the dark from said memory means which have been obtained from an image of the reference pattern received directly or by way of a normal transparent article by said image sensor;

average value calculating means for calculating an average value between those two of the picture element data of the reference pattern from said memory means obtained from an image of the reference pattern received through an object by said image sensor which are spaced by a predetermined number of picture elements with reference to the pitch detected by said reference pattern pitch detecting means;

threshold value setting means for setting upper and lower threshold values from the average value;

reference pattern erasing means for successively comparing the picture element data from said memory means with the upper and lower threshold values to determine the picture element data as the dark when the picture element data fall between the upper and lower threshold values but determine the picture element data as the bright in any other case to erase data based on the reference pattern;

bright/dark determining means for counting numbers of data of those picture elements in a unit area

around each of the picture elements which are determined as the bright and the dark and determining the bright or the dark of the picture element in accordance with a difference between the thus counted numbers; and

defect discriminating means for discriminating a defect from numbers of data of picture elements of the bright and the dark determined by said bright-/dark determining means.

8. An apparatus as claimed in claim 7, wherein said average value calculating means calculates an average value between those two of the picture element data of the reference pattern from said memory means obtained from an image of the reference pattern received through an object by said image sensor which are spaced by a distance equal to one half the detected pitch.

9. An apparatus as claimed in claim 7, wherein said threshold value setting means sets upper and lower threshold values by adding and subtracting a correction value to and from the average value, respectively.

10. An equipment for inspecting a transparent or translucent object for a defect, comprising:

means for successively positioning an object at first, second and third inspecting positions;

an optical system provided for each of the first, second and third inspective positions for projecting light of a reference pattern diametrically upon an object at the inspecting position over an angle of about 60 degrees around an axis of the object and photographing light transmitted through the object to obtain data of picture elements of an image of the received light;

a rotating apparatus interposed between the first and second inspecting positions and between the second and third inspecting positions for rotating an object by 60 degrees in one direction around its axis; and

a picture image processing apparatus connected to each or all of the optical systems for detecting a defect of an object from the data of picture elements from said optical system or systems, wherein said picture image processing apparatus or each of said picture image processing apparatus includes:

memory means for receiving and storing therein data of picture elements from the corresponding optical system or the optical systems;

reference pattern pitch detecting means for detecting the pitch of the reference pattern from numbers of picture element data of the bright and the dark from said memory means which have been obtained from an image of the reference pattern received directly or by way of a normal transparent article by said optical system;

average value calculating means for calculating an average value between those two of the picture element data of the reference pattern from said memory means obtained from an image of the reference pattern received through an object by said optical system which are spaced by a predetermined number of picture elements with reference to the pitch detected by said reference pattern pitch detecting means;

threshold value setting means for setting upper and lower threshold values from the average value;

reference pattern erasing means for successively comparing the picture element data from said memory means with the upper and lower threshold values to determine the picture element data as the dark when the picture element data fall between the upper and lower threshold values but determine the picture element data as the bright in any other case to erase data based on the reference pattern;

bright/dark determining means for counting numbers of data of those picture elements in a unit area around each of the picture elements which are determined as the bright and the dark and determining the bright or the dark of the picture element in accordance with a difference between the thus counted numbers; and

defect discriminating means for discriminating a defect from numbers of data of picture elements of the bright and the dark determined by said bright-/dark determining means.

11. An equipment for inspecting a transparent or translucent object for a defect, comprising:

means for successively positioning an object at a pair of inspecting positions;

first and second optical systems provided for one of the inspecting positions for projecting light of a reference pattern diametrically upon an object at the inspecting position over different contiguous angular ranges of about 60 degrees around an axis of the object and photographing light transmitted through the object to obtain data of picture elements of images of the received light;

a third optical system provided for the other of the inspecting positions for projecting light of the same reference pattern diametrically upon an object at the inspecting position over an angular range of about 60 degrees around the axis of the object and photographing light transmitted through the object to obtain data of picture elements of an image of the received light;

a rotating apparatus interposed between the inspecting positions for rotating an object by 60 degrees in one direction around its axis so that said first, second and third optical systems may photograph different contiguous angular ranges of an object; and

a picture image processing apparatus connected to each or all of said first to third optical systems for detecting a defect of an object from the data of picture elements from said optical system or systems, wherein said picture image processing apparatus or each of said picture image processing apparatus includes:

memory means for receiving and storing therein data of picture elements from the corresponding optical system or the optical systems;

reference pattern pitch detecting means for detecting the pitch of the reference pattern from numbers of picture element data of the bright and the dark from said memory means which have been obtained from an image of the reference pattern received directly or by way of a normal transparent article by said optical system;

average value calculating means for calculating an average value between those two of the picture element data of the reference pattern from said memory means obtained from an image of the reference pattern received through an object by said optical system which are spaced by a predetermined number of picture elements with reference to the pitch detected by said reference pattern pitch detecting means;

threshold value setting means for setting upper and lower threshold values from the average value;

reference pattern erasing means for successively comparing the picture element data from said memory means with the upper and lower threshold values to determine the picture element data as the dark when the picture element data fall between the upper and lower threshold values but determine the picture element data as the bright in any other case to erase data based on the reference pattern;

bright/dark determined means for counting numbers of data of those picture elements in a unit area around each of the picture elements which are determined as the bright and the dark and determining the bright or the dark of the picture element in accordance with a difference between the thus counted numbers; and

defect discriminating means for discriminating a defect from numbers of data of picture elements of the bright and the dark determined by said bright-/dark determining means.

12. An equipment for inspecting a transparent or translucent object for a defect, comprising:

means for successively positioning an object at an inspecting position;

first, second and third optical systems provided for the inspecting position for projecting light of a reference pattern diametrically upon an object at the inspecting position over different contiguous angular ranges of about 60 degrees around an axis of the object and photographing light transmitting through the object to obtain data of picture elements of images of the received light; and

a picture image processing apparatus connected to each or all of said first to third optical systems for detecting a defect of an object from the data of picture elements from said optical system or systems, wherein said picture image processing apparatus or each of said picture image processing apparatus includes:

memory means for receiving and storing therein data of picture elements from the corresponding optical system or the optical systems;

reference pattern pitch detecting means for detecting the pitch of the reference pattern from numbers of picture element data of the bright and the dark from said memory means which have been obtained from an image of the reference pattern received directly or by way of a normal transparent article by said optical system;

average value calculating means for calculating an average value between those two of the picture element data of the reference pattern from said memory means obtained from an image of the reference pattern received through an object by said optical system which are spaced by a predetermined number of picture elements with reference to the pitch detected by said reference pattern pitch detecting means;

threshold value setting means for setting upper and lower threshold values from the average value;

reference pattern erasing means for successively comparing the picture element data from said memory means with the upper and lower threshold values to determined the picture element data as the dark when the picture element data fall between the upper and lower threshold values but determined the picture element data as the bright in any other case to erase data based on the reference pattern;

bright/dark determining means for counting numbers of data of those picture elements in a unit area around each of the picture elements which are determined as the bright and the dark and determining the bright or the dark of the picture element in accordance with a difference between the thus counted numbers; and

defect discriminating means for discriminating a defect from numbers of data of picture elements of the bright and the dark determined by said bright-/dark determining means.

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